Step-Cut Bone-Graft Technique for Osteoarthritis with Severe Glenoid Bone Loss

Vani Sabesan, MD, Vinay Sharma, BA, Mark Callanan, MD, MA, Jason Ho, MD, and Joseph Iannotti, MD, PhD

Based on an original article: *J Bone Joint Surg.* 2013;95(14):1290-6.

Introduction

We describe a bone-graft technique, for shoulder arthroplasty in patients with severe glenoid bone loss, that utilizes a “step cut,” a trapezoidal bone wedge from the resected humeral head, and graft fixation with screws placed from posterior to anterior through the graft.

The use of bone grafts in total shoulder arthroplasty to correct severe glenoid retroversion or bone loss is a technically demanding procedure. Bone-grafting techniques are challenging and have demonstrated variable clinical results, with a high complication rate due to failure of graft incorporation or loss of glenoid fixation¹⁻⁴. Nonetheless, grafting procedures provide an alternative for restoring normal glenohumeral stability for patients with excessive bone loss. In cases with more severe glenoid retroversion, generally $>20^\circ$, bone-grafting of the posterior aspect of the glenoid can improve the surgeon's ability to place the glenoid components in the patient's normal version without excessive reaming of the anterior aspect of the glenoid. Correction of glenoid version is important to prevent eccentric loading. Asymmetric reaming to correct version may result in excessive bone removal such that the glenoid vault will not be deep enough for the surgeon to implant a glenoid component without perforation of the glenoid wall by the component pegs or keel⁵. In addition, excessive reaming may overmedialize the joint line. The bone-graft technique described in this paper utilizes a “step cut” and a trapezoidal-shaped wedge of bone obtained from the resected humeral head. Graft fixation is achieved by placing screws placed from posterior to anterior through the graft to compress the graft into the step-cut surface of the native glenoid.

The step-cut bone graft technique is done in the following stages (Video 1).

Step 1: Preoperative Planning

Carry out preoperative planning for the step-cut procedure.

- Obtain preoperative true anteroposterior (Grashey) and axillary radiographs and a computed tomography (CT) scan of the affected shoulder.
- The bone loss and glenoid version for each patient can be evaluated on two-dimensional midlevel axial images, as defined by Friedman et al.⁶, created from a preoperative CT scan. Use of three-dimensional CT imaging, if available, with the method described by Scalise et al.⁷ can provide better precision. This validated method, in which the glenoid plane is defined by three glenoid face points (Fig. 1-A), allows an overall assessment of the average deformity defined by a plane. Glenoid bone loss is quantified according to the difference from normal defined glenoid anatomy based on the vault model and pathological glenoid articular surface based on midlevel axial cuts (Fig. 1-B).
- Measure the amounts of bone loss and glenoid retroversion on a preoperative CT scan to estimate the appropriate bone graft size.

Step 2: Surgical Approach and Preparation of the Glenoid

Expose the glenoid for bone graft insertion, taking care to avoid excessive reaming.

- Perform a standard deltopectoral approach followed by either a tenotomy or a lesser tuberosity osteotomy for the subscapularis takedown.
- Then perform a standard humeral head osteotomy at the anatomic neck after removing humeral osteophytes as appropriate.
- Excise the anterior and inferior aspects of the capsule from the glenoid rim. Excision of the anterior and inferior aspects of the capsule from the humeral to the glenoid insertion improves glenoid exposure and postoperative range of motion.

- Ream the anterior aspect of the glenoid in a trajectory perpendicular to the plane of the scapula to correct glenoid version to neutral^{8,9} (Video 1, Time Point 1:40). Ream the glenoid to a depth necessary to achieve a uniform concave surface on the anterior half of the glenoid from approximately the superior pole to the inferior pole of the glenoid.
- After reaming the high anterior side of the glenoid, burr the posterior half of the glenoid from superior to inferior as a “step cut” to a level approximately the same as the largest glenoid defect (area of greatest bone loss) (Fig. 2; Video 1, Time Point 1:49).

Step 3: Prepare the Glenoid Bone Graft

Cut the appropriately sized glenoid bone graft from the resected humeral head.

- Measure the posterior defect with a ruler to determine the superior-to-inferior and anterior-to-posterior dimensions as well as the depth needed for the bone graft (Video 1, Time Point 2:15).
- Use these measurements to create a paper template. Place the template onto the step-cut area and ensure that the template is the correct size and shape (Fig. 3; Video 1, Time Point 2:20). Using the template, mark the excised humeral head for graft size and shape.
- With a microsagittal saw, cut the bone graft to the correct dimension and thickness (Video 1, Time Point 2:54). The resulting graft should be at least 3 mm thicker than the depth of the measured glenoid bone defect. The graft cut is made to preserve some cortical bone posteriorly, with the remainder of the graft being cancellous bone. The graft has a trapezoidal shape with the thickest part of the graft placed posteriorly, usually about 9 to 12 mm thick posteriorly and about 3 to 4 mm thick medially (Fig. 3).

Step 4: Insert and Fix the Glenoid Bone Graft

Position the bone graft in the glenoid defect and stabilize it with screws.

- To facilitate graft insertion and screw placement, place a lamina spreader on the intact anterior aspect of the glenoid and the humeral osteotomy site (Fig. 4). Position the arm so that the humeral osteotomy surface is parallel to the surface of the glenoid. When the lamina spreader is opened the space created between the humerus and glenoid is sufficient to place the graft without

interference from retractors typically placed along the posterior glenoid rim.

- Place the bone graft into the glenoid defect and hold the graft with a bone tamp or your fingers (Video 1, Time Point 3:34). Then place 2.0-mm Kirschner wires through a percutaneous stab incision along the posterior aspect of the shoulder to obtain provisional fixation in the center of the graft (Fig. 5-A). Next place two additional 2.0-mm guidewires above and below the center Kirschner wires in preparation for cannulated screw fixation.
- Using the superior and inferior guide-pins, drill for 4.0-mm cannulated cancellous screws through the posterior margin of the graft into the native anterior glenoid vault through the anterior cortex (Video 1, Time Point 3:47); the aim is to place the screws into the thickest part of the bone graft and into the remaining native glenoid (Fig. 5-B). The optimal trajectory of screws is shown in Figure 5-B; the screws need to be placed obliquely in the anterior-posterior plane and at the superior and inferior margins of the glenoid or graft in order to avoid the large central peg or keel component.

Step 5: Prepare the Glenoid Surface

Create an even concave surface between the anterior aspect of the glenoid and the posterior aspect of the graft.

- After the graft is securely fixed, use a burr or a glenoid reamer with light pressure to create an even concave surface between the anterior aspect of the glenoid and the posterior aspect of the graft (Video 1, Time Point 4:29). Take care not to damage the graft or fixation. In most cases, it is safest to use a handheld burr to prepare the surface (Fig. 6).
- Perform the remainder of the preparation for the implant using the standard manufacturer's instruments for a peg or keeled component (Video 1, Time Point 4:40).

Step 6: Place the Glenoid Implant

Position the glenoid component following step-cut graft implantation.

- Insert the glenoid trial to verify component seating and stability (Fig. 6; Video 1, Time Point 5:05).
- Irrigate the glenoid with pulsatile lavage and then hydrogen peroxide or thrombin to optimize glenoid-cement fixation, and then insert the cement in a standard fashion into peripheral

peg holes or around the keel. Be sure to avoid placing cement between the glenoid and graft interface. Impact the final pegged or keeled ultra-high molecular weight glenoid component (Fig. 6).

Postoperative Rehabilitation

Postoperative rehabilitation is mostly the same as that for standard total shoulder replacement without bone-grafting.

- The postoperative rehabilitation is the same as that for standard total shoulder replacement without use of a bone graft in all respects except for a delay in starting cross-body adduction stretching, which is begun at six weeks rather than our usual protocol of starting it at two weeks.
- Typically, patients are treated for two to four weeks with a small pillow abduction sling and passive supine forward flexion and external rotation stretching. Six weeks after surgery, passive cross-body adduction, active elevation, and short-arc Thera-Band strengthening are started. More advanced strengthening should be progressed on an individualized basis.

Results

The range of motion improved significantly in our study of twelve patients¹⁰ ($p < 0.001$). At the time of final follow-up, the patients had an average of $156.5^\circ \pm 17^\circ$ (range, 110° to 170°) of forward flexion, with an average improvement of 27.2° ($p = 0.006$), and an average of $49^\circ \pm 21^\circ$ (range, 30° to 90°) of external rotation, with an average improvement of 15.9° ($p = 0.03$). Patient-reported Penn scores demonstrated a good or excellent clinical result in ten of the twelve patients. The total Penn score improved significantly ($p < 0.001$) from a mean of 38.7 (range, 19 to 52) preoperatively to a mean of 79.4 (range, 17 to 100) postoperatively.

Preoperatively, the glenoid retroversion angles averaged $44^\circ \pm 14^\circ$, and glenoid bone loss averaged 15.2 ± 8.3 mm. At an average of fifty-three months postoperatively, follow-up radiographs demonstrated good graft incorporation with minimal absorption in ten of the twelve patients. Two of the twelve patients had complications associated with healing of the graft and

graft fixation that required revision surgery. Two patients had broken screws seen on radiographs at one year and eight years after the initial surgery.

What to Watch For

Indications

- Severe glenoid bone loss and/or glenoid retroversion in the setting of glenohumeral osteoarthritis ($>60^\circ$ or with substantial medialization)
- Abnormal or atypical glenoid wear and erosion (anterior or central glenoid bone loss or asymmetric posterior glenoid bone loss not conducive to a trapezoidal bone-grafting technique)

Contraindications

- Grafting is not necessary for mild glenoid bone loss
- Subscapularis insufficiency
- Rotator cuff insufficiency
- Inadequate glenoid bone volume

Pitfalls & Challenges

- This technique requires extensive preoperative planning and intraoperative preparation of the glenoid bone graft.
- Performing the step-cut procedure and trapezoidal graft placement can be challenging but allows for excellent graft compression and stability.
- Screw placement and obtaining optimal fixation length can be technically challenging. Using percutaneous incisions posteriorly can optimize guidewire and screw placement.
- We recommend using 4.0-mm cancellous screws for optimal screw selection and fixation.

Clinical Comments

- What is the optimal screw biomaterial and size to maximize stability and outcomes following glenoid bone-grafting?
- What is the maximum postoperative glenoid retroversion that can be tolerated without bone-graft failure?

Vani Sabesan, MD
Vinay Sharma, BA

Western Michigan University School of Medicine, 1000 Oakland Drive, Kalamazoo, MI 49008. E-mail address for V. Sabesan: sabes001@gmail.com

Mark Callanan, MD, MA

Harvard Combined Orthopaedic Residency Program, 55 Fruit Street, White 535, Boston, MA 02114

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. One or more of the authors, or his or her institution, has had a financial relationship, in the thirty-six months prior to submission of this work, with an entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. No author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

References

1. Keller J, Bak S, Bigliani LU, Levine WN. Glenoid replacement in total shoulder arthroplasty. *Orthopedics*. 2006 Mar;29(3):221-6.
2. Hill JM, Norris TR. Long-term results of total shoulder arthroplasty following bone-grafting of the glenoid. *J Bone Joint Surg Am*. 2001 Jun;83(6):877-83.
3. Neyton L, Walch G, Nové-Josserand L, Edwards TB. Glenoid corticocancellous bone grafting after glenoid component removal in the treatment of glenoid loosening. *J Shoulder Elbow Surg*. 2006 Mar-Apr;15(2):173-9.
4. Scalise JJ, Iannotti JP. Bone grafting severe glenoid defects in revision shoulder arthroplasty. *Clin Orthop Relat Res*. 2008 Jan;466(1):139-45. Epub 2008 Jan 3.
5. Nowak DD, Bahu MJ, Gardner TR, Dyrszka MD, Levine WN, Bigliani LU, Ahmad CS. Simulation of surgical glenoid resurfacing using three-dimensional computed tomography of the arthritic glenohumeral joint: the amount of glenoid retroversion that can be corrected. *J Shoulder Elbow Surg*. 2009 Sep-Oct;18(5):680-8. Epub 2009 May 31.
6. Friedman RJ, Hawthorne KB, Genev BM. The use of computerized tomography in the measurement of glenoid version. *J Bone Joint Surg Am*. 1992 Aug;74(7):1032-7.
7. Scalise JJ, Codsi MJ, Bryan J, Brems JJ, Iannotti JP. The influence of three-dimensional computed tomography images of the shoulder in preoperative planning for total shoulder arthroplasty. *J Bone Joint Surg Am*. 2008 Nov;90(11):2438-45.
8. Matsen F, Lippitt SB, Sidles JA, Harryman DT. Practical evaluation and management of the shoulder. Philadelphia: WB Saunders; 1994. p 192-210.
9. Rockwood CA, Matsen FA, Wirth MA, Harryman DT. The shoulder. Philadelphia: WB Saunders; 1998. p 850.
10. Sabesan V, Callanan M, Ho J, Iannotti JP. Clinical and radiographic outcomes of total shoulder arthroplasty with bone graft for osteoarthritis with severe glenoid bone loss. *J Bone Joint Surg Am*. 2013 Jul 17;95(14):1290-6.

Figures

Fig. 1

The glenoid plane is defined by three points (**Fig. 1-A**), and glenoid bone loss is measured as the difference from the normal anatomy based on the vault model and the pathological anatomy based on midlevel axial cuts (**Fig. 1-B**).

Fig. 2
The posterior side of the glenoid is burred as a step cut to a depth similar to the defect.

Fig. 3
The superior-inferior and anterior-posterior dimensions of the prepared posterior defect are measured, and a template is cut to match the shape and size of the posterior defect. This template is then used to mark the humeral head, which is cut to create a graft of the correct size and shape. It should be noted that the graft is thinner on the medial side than on the lateral side. The graft has a trapezoidal shape. The head is cut so that it will be thicker than that of the actual defect.

Fig. 4
Access to the joint is achieved by placing a lamina spreader into the joint in contact with the anterior aspect of the glenoid and the humeral osteotomy surface. The posterior aspect of the glenoid is prepared as a step cut. A step cut is made in the glenoid from superior to inferior with use of a burr to a depth that approximates the deepest part of the glenoid defect.

Fig. 5
The bone graft is stabilized with 2.0-mm Kirschner wires (**Fig. 5-A**) as well as 4.0-mm cannulated cancellous screws (**Fig. 5-B**).

Fig. 6
The graft and native glenoid are reamed to yield a uniform surface (**Fig. 6-A**). The glenoid is prepared with use of standard methods to receive the fixation portions of the glenoid component (**Fig. 6-B**). A trial component is first placed to verify position and stability (**Fig. 6-C**), after which the final component is impacted (**Fig. 6-D**).